

# Critical Considerations For A Closed-Loop Medication Administration System

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## Abstract

*In recent years, the serious consequences of medical error are realized by both healthcare practitioners and the public because of the critical direct injury towards the involved patients and the high indirect costs subsequently all around the world. The utilization of information and communication technology in this field is recognized to have the potential of improving the quality of clinical treatment and reducing medical errors. To achieve safe and high-quality healthcare service, a closed-loop medication administration is an effective solution since all the processes are monitored and recorded by the system. Among all the clinical staff, nurses play the most integral role in the whole patient care process in hospitals, including medication administration process with the potential of the medical errors to be recognized, handled and prohibited by nursing staff. Mobile nursing system may have the possibility to improve the efficiency and patient safety through the achievement of closed-loop medication administration.*

## Key Words

Medical error; closed-loop medication administration; mobile nursing system; questionnaire; semi-structured interviews

## 1. Introduction

In recent years, the severe consequences of medical error are realized by both healthcare practitioners and the public because of the critical direct injury towards the involved patients and the high indirect costs subsequently all around the world [1, 2]. Thus, a critical problem is to reduce the

occurrence of medical errors and improve the efficiency of clinical treatment at the same time [3]. The utilization of information and communication technology (ICT), in particular the tools and Techniques of the Internet of Things (IoT) in the healthcare field is recognized to have the potential of improving the quality of clinical treatment and reducing medical errors [4]. Moreover, information and communication technology has already shown its significance in improving the effectiveness and outcome of healthcare delivery.

To achieve safe and high quality healthcare service, the whole process of medication administration needs to be examined [5]. Since there are various steps from the physicians prescribing orders to the orders being performed and documented according to the type of the order, the concept of closed-loop medication administration is a strategy to deliver medication safely [6].

A closed-loop medication administration system is a medication administration system which records and traces every step through the prescribing to implementing of every single order with automated identification technology [7]. As a result, some errors can be identified and avoided with an automated check and remind technique [8]. Even if medical errors occur, the records can be retrieved and the cause of the error can be quickly revealed so that appropriate corrective action can be quickly taken. Therefore, closed-loop medication administration can reduce medical errors since all the processes are monitored and recorded by its information system [9].

Among all the clinical staff, nurses play an integral key role in the whole patient care process in hospitals including medication administration and most of the medical errors could be recognized, handled and prevented by nursing staff [10]. According to [11], although the medication order is

prescribed by the physicians and dispensed by the pharmacists, medication errors are often encountered in nursing care service because the rest of the processes such as preparing, checking, giving medications, monitoring the effectiveness or the adverse reaction are more likely to lead to medical errors; hence all the errors have the possibilities to be found and prevented by nurses [12].

Mobile nursing system is the information system used by nurses to record their daily work and make it possible to enquire for all the related information anywhere anytime in the clinical institutions with the use of technology such as WLAN, hand-held terminal of personal digital assistant (PDA), bar-code scanning and so on [13]. Mobile nursing systems can smooth the working flow and patient flow through transforming the information of patients and treatment to everywhere at any time [14]. The mobile nursing systems can also record every step of the implementation of the prescribing order timely and accurately [13]. As a result, mobile nursing systems may have the possibility to improve the efficiency and patient safety through the achievement of closed-loop medication administration [14].

The research aims to explore the following major question:

How can a mobile nursing system be used to achieve closed-loop medication administration to deliver high quality and safe nursing care?

In order to answer this question, the following two sub-questions had also been evaluated:

- i. What are the key issues in designing and using a mobile nursing system in the implementation of the closed-loop medication administration?
- ii. What are the benefits and problems when utilizing mobile nursing system to achieve closed-loop medication administration?

## 2. Methodology

In this study, a mixed research approach combined qualitative and quantitative method was adopted based on a hospital which is located in a major metropolitan region in China. A case study including semi-structured interviews and questionnaires was adopted to investigate the research questions. All the data collected from the above research methods were analysed and discussed in order to explore the research questions in a deep manner.

### *Case study*

A single exemplar case study is appropriate for this study since the case represents, illustrates and examines existing theory and insights from this case are used as a prelude to future research [15]. A single case study of designing and implementing a mobile nursing system with the purpose of completing closed-loop medication administration in a large hospital located in China has been conducted to investigate the research question. The case site is a large hospital contains around 3000 inpatients beds so the situation there is very complicated and therefore the solution would be reliable to be spread since various kinds of problem would be encountered and solved in this single case site. In the data collection phase, some kinds of qualitative research techniques including semi-structured interviews, focus group interview, and site observation were utilised to achieve primary data and secondary data was acquired through reading related files and achieves.

### *Questionnaire*

Since filling out a questionnaire is less time-consuming than interviewing, more nurses can participate in the questionnaire. A structured questionnaire was designed to include the basic information and opinion of the users from the site hospital. The questionnaire was developed specifically for the study, based on a literature review, experts' suggestions, and the results of a pre-survey study. The pre-survey study was conducted to collect feedback from respondents and survey experts, and the researchers reached consensus regarding the final survey by making necessary revisions to the original version. The questionnaire consisted of 18 questions pertaining to demographic information, satisfaction with mobile nursing information system, and the effectiveness of the system. Five questions were used to collect the following demographic information: gender, age, educational background, role as a nurse, and system usage time. Seven questions were designed to collect the information regarding satisfaction degree or dissatisfaction degree towards the feedback on the hardware and software of the system. The focused points included the portability of the tablet PC, the stability of the wireless network, the navigation of the system, the information display on the tablet, the ease of data entry, the system response speed and the training. The related answers were: very satisfied / satisfied / indifferent / dissatisfied / very dissatisfied. The last six questions were used to collect the following information regarding effectiveness of the mobile nursing information system: the accuracy of

patient identification, patient safety, the work efficiency, the process optimization, the patient satisfaction and the accuracy and data security. The related answers were consisted of Likert scale items where respondents were asked to choose from a five points range – strongly agree / agree / neither agree nor disagree/ disagree / strongly disagree.

### ***Interviews***

In addition to the questionnaire, interviews were designed in order to include the opinion of the users in the case hospital. All the interviews were audio-recorded for verbatim transcription prepared by a professional transcriptionist, checked for accuracy against the sound files by the interviewers, and corrected where necessary [16]. The data collected was then interpreted through the lens of Activity Theory [17]. In the data analysis phase, thematic analysis and arithmetic analysis were adopted to acquire the research results.

## **3. Results**

The mobile nursing system was designed for inpatient nursing service, which covers the functions of the whole medical service flow of inpatients and nursing quality management. Based on the detailed analysis of the actual work situation of nurses in the hospital, an efficient and convenient mobile nursing information system was designed and implemented, so as to realize the transformation of nursing work from manual nursing management to automatic computer management. The new system was launched in a pilot clinical ward before utilized in the whole hospital since the real situation in the hospital was very sophisticated than what could be imaging. The interviews and Questionnaires were conducted six months after the system implementation in the hospital.

### ***Questionnaire***

Led by hospital's contact person, trained investigators distributed questionnaires to nurses, and asked them to complete it, independently, voluntarily, and autonomously. Questionnaires were collected immediately after completion. In total, 30 questionnaires were distributed, and all were collected, providing a response and valid rate of 100%. All valid questionnaire responses were recorded and entered into EXCEL. SPSS (version 22.0, IBM, Chicago, IL, USA) was used to perform statistical analysis.

The participants' basic demographic information is shown in Table 1. Regarding respondents' gender, the number of women included in the study was higher relative to that of male, with a male-to-female ratio of 1:5. With respect to age group, most participants were aged between 20 and 40 years old, and the largest age group was between 20 and 30 years old. Regarding educational background, most respondents held bachelor degree at least, and very few held degrees below bachelor's level. Regarding the respondents' job titles, most residents were senior nurse, followed by supervisor nurse and above, the nurse was the lowest, but the difference was marginal. Regarding the length of usage of the mobile nursing information system, 18 respondents used the system for more than 181 days, followed by 11 respondents who used the system for a period between 91 and 180 days, there was only one nurse used the system for a period between 31 and 90 days while no result recorded less than 30 days.

Results about satisfaction with the various parts of the mobile nursing information system are shown in Table 2. For the answers, 1 represents great satisfaction, 5 represents very dissatisfied, the smaller the score, the more satisfied from the participants. Regarding the seven questions, the mean satisfaction is 3 which reveals most participants were satisfied with the mobile nursing information system. From the mean value of all the questions, it can be seen that the best satisfying number (2.07) is about the training of how to use the mobile nursing system and tablets. And then the more satisfied aspects are the information display of tablets (2.50), the convenience of information entry (2.70) and the system navigation design (2.80). It should be noticed that the response speed of the system (3.90) and the stability of wireless networks (3.90) are the most unsatisfied points. Moreover, it was worth mentioning that the portability of tablets (3.13) needed to be strengthened as well. Another interesting rule is the lower variance, the more consensuses on the feedback which are consistent with the variance results (0.27-0.95).

Results regarding effectiveness of the mobile nursing information system are shown in Table 3. For the answers, 1 represents agree strongly, 5 represents strongly disagree, the smaller the score, the more agree with the investigated view. For the mean value of these six questions, the questions that scored lowest was improve the accuracy of patient identification (1.50), and next was agree with improves patient safety (1.60). The more agreed point also included the patient satisfaction (2.8) and the accurate and safe data storage (2.23). The points of

optimized the workflow (3.00) and increased the work efficiency (3.60) had not been agreed obviously. One difference with the satisfaction part is that the average score is lower than satisfaction survey, that is, respondents pretty much agreed that mobile nursing information system improved accuracy and safety. Consistent with the previous section, the basic rule is the lower variance, the more consensus on the feedback which are consistent with the variance results (0.39-1.24).

### ***Semi-structured interviews***

For this study, semi-structured interviews were conducted with 15 nurses in the site hospital. One of the objectives of this study was to conduct interviews to unearth further information on the issues that emerged in the questionnaire survey. In previous study we learned that the degree of information demand was high while degree of information satisfaction was low during the interactions between physicians and nurses and they both expected high on the adoption of new information technologies [18]. As shown in Table 4 below, the interviews included three aspects comprising the benefits of mobile nursing system, the current situations and problems of the system, and evaluation on the improvement of nursing care through the usage of information technology

The interviews were conducted and recorded upon obtaining the approval of the interviewees, and the interview recordings did not reveal sensitive personally identifiable information such as the names and contact methods of the interviewees. Upon completion of the interviews, the interviews were transcribed from audio into text, and the interview contents were analysed using the inductive conventional content analysis approach [19]. Researchers read the transcribed texts several times to understand the information conveyed in the interviews. The key information of the interview contents was extracted, coded, and subsequently categorized in three themes: benefits, problems and advices.

### ***Benefits from using mobile nursing information system***

The nurses were generally satisfied with the current situation of the mobile nursing information system. Firstly, nearly all of the interviewees mentioned that there were no obvious problems in terms of patient identity verification and implementation of doctor's orders, and the main reasons were that system training in the early stage

was quite clear and comprehensive. Notably, some interviewees indicated that mobile nursing information system could automatically record the actual implementation time and the operator. If the information was wrong, the system displayed a mismatch, then warning information would appear on the screen according to the reasons to remind the nurses. Therefore, the mobile nursing information system improved the safety of clinical medication, effectively prevented and reduced the incidence of medical errors, and improved the level of clinical nursing management.

On the other hand, patient wristbands were equipped with important information signs for patient identification and verification. By scanning the two-dimensional code, identification information of patients could be identified and managed, which effectively improved the quality and efficiency of patient information management. Thus patient compliance was increased by means of mobile nursing information system because of trust and professionalism.

### ***Dissatisfaction with the mobile nursing information system***

With regards to the usage of the current mobile nursing information system, some of the interviewees said that the system was not running smoothly in some corners, which was likely due to weak network coverage in that area. On another note, the interviewees mentioned that they have encountered occasional system errors such as network disruptions and software crashes that significantly affected their work efficiency and regular operations. These situations even could lead to the loss of information, and the problem required to be fixed.

### ***Anticipation of the mobile nursing information system***

For this mobile nursing system, there were still some aspects that needed to be improved. The stability of the portable device, the stability of the wireless network, the usability of the software and the system support all needed to be enhanced according to the findings of the study from different research methods. Since the screen of the PDA is small to display too many information and it was the most important tools for nurses' daily job, the convenience, the navigation need to be enhanced to improve the usability of the system. For the maintenance period after implementation, the interviewees generally recommended that technical

personnel should take regular on-site visits to check and refine the system.

## 4. Discussion

The results revealed that the closed-loop medication administration can be achieved through a well-designed and implemented mobile nursing system. The mobile nursing system covered the complete process of medical orders execution procedure and provided information access, data records and data management. It broke through the time limitation and space constraints through constructing the wireless network and the utilization of the PDA devices.

There were some key factors for the successful implementation of the mobile nursing system. The requirement analysis should be based on the comprehensive understanding of the workflow of nurses' daily job and the whole medical execution process with the early involvement of nurses from the beginning of the project. The system design should be focused on user-centered principle whereas the scope of system functions should be defined clearly and some functions should be achieved as the improvement after the system implementation. For system development, not only the development of the mobile nursing system but also the development and debugging of interfaces with other information systems were important and should be paid more attention. The full covered training for users was critical for the successful implementation. The selection of pilot ward should be considered with the real situation and requirements of the hospital and the pilot period should not last too long.

With the help of the system, the clinical professionals including the nurses and the doctors did their job more efficiently and accurately and it also improved the patient safety and patient satisfaction. Regarding the interview and questionnaire, the nurses were generally satisfied with the current situation of mobile nursing information system and new simplified and efficient workflow, especially in wrist band recognition and accuracy of identification. The information access and the data recording were very convenient with the new system and the PDA. In addition to this, the benefits for nursing management were obvious because of the traceable medical execution process, the timely quality control and the available data analysis for decision making support. As a result of the improvement of the quality medical service, patients experience and patients satisfaction were also obtained enhancement. On the other hand, there were still some problems encountered in the design and implementation of the mobile nursing

system. The stable of portable device and wireless network were not satisfied by the users and needed to be enhanced.

For future studies, recommendations can be given according to the results and findings of this study. On one hand, from the aspect of system optimization, some decision support functions for the improvement of work efficiency and accuracy need to be investigated and the data analysis for nursing management could be explored deeply. In addition to this, the security issues should be paid more attention as the utilization of internet and mobile technology has increased the risk for data compromise. On the other hand, from the perspective of theoretical application, since the Activity Theory was utilized in this study for the evaluation of the MNIS towards medication administration for nurses, some further utilization of Activity Theory such as evaluating the effects towards other healthcare processes and user interface design adopting Activity Theory method could be attempted in the future study.

## 5. Conclusions

The research question "How can a mobile nursing system be used to achieve closed-loop medication administration to deliver high quality and safe nursing care?" is answered through answering the two sub-questions. Firstly, the early involvement of users, comprehensive understand of the workflow and medical execution process, user-centered design, election pilot case, interfaces with other information systems and full coverage training were detected as key issues in the successful implementation of mobile nursing system and closed-loop medication administration. Furthermore, the findings identified that the benefits from the system included convenient information access, timely and accurate recording, improvement of medical quality, patient safety and patient satisfaction. The problems which needed to be improved were the stability of the portable device and wireless network. Overall, the closed-loop medication administration was achieved through the implementation of the mobile nursing system. All the clinical professionals received benefits from the system. This research shows a successful attempt to closed-loop medication administration through the implementation of a well-designed mobile nursing system and the final completed system was both effective and diffusible to other healthcare institutions especially in China.

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